Università degli Studi di Modena e Reggio Emilia
Dipartimento di Economia Politica

Materiali di discussione

\\ 619 \\

Innovative interventions in support of innovation networks. A complex system perspective to public innovation policy and private technology brokering

by

Federica Rossi[1]
Margherita Russo[2]
Stefania Sardo[3]
Josh Whitford[4]

September 2009

[1] Università degli Studi di Torino
e-mail: federica.rossi@unito.it

[2] corresponding author
Università degli Studi di Modena e Reggio Emilia
Dipartimento di Economia Politica
Via Berengario, 51 41100 Modena, Italy
e-mail: margherita.russo@unimore.it

[3] stefania.sardo@gmail.com

[4] Department of Sociology
Columbia University, New York (US)
jw2212@columbia.edu

Credits

A preliminary version of this paper has been presented by Margherita Russo at the conference on “Innovation in complex social systems”, Dublin, December 10-12, 2008, and at the Phoenix Innovation Study’s workshop on “The Future of Innovation Studies” organized by the School of Human Evolution and Social Change, Arizona State University, AZ, 17th February 2009. We wish to thank the participants at these presentations for their comments and lively discussions.
A shorter version of the paper will be published in *Innovation in Complex Social Systems*, (edited by Petra Ahrweiler), London, Routledge, 2010

Abstract

The linear model of innovation has been superseded by a variety of theoretical models that view the innovation process as systemic, complex, multi-level, multi-temporal, involving a plurality of heterogeneous economic agents. Accordingly, the emphasis of the policy discourse has shifted over time. It has gone from a focus on direct public funding of basic research as an engine of innovation, to the creation of markets for knowledge goods, to, eventually, the acknowledgement that knowledge transfer very often requires direct interactions among innovating actors. In most cases, these interventions attempt to facilitate the match between "demand" and "supply" of the knowledge needed to innovate. A complexity perspective calls for a different framing, one focused on the fostering of process characterized by multiple agency levels, multiple temporal scales, ontological uncertainty and emergent outcomes. The article explores what it means to design interventions in support of innovation processes inspired by a complex systems perspective. It does so by analyzing two different examples of coordinated interventions: an innovative public policy funding networks of innovating firms, and a private initiative supporting innovation in the mechanical engineering industry thanks to the set up of a technology broker. Relying on two unique datasets recording the interactions of the various organizations involved in these interventions, the article combines social network analysis and qualitative research in order to investigate the dynamics of the networks and the roles and actions of specific actors in fostering innovation processes. Building upon this comparative analysis, some general implications for the design of coordinated interventions supporting innovation in a complexity perspective are derived.

Keywords: Innovation policy; local development policies; regional development policies; evaluation management

Classification-JEL: D78; O31; O32; O38; R58

1. Introduction

The increased emphasis on the role of innovation as a primary driver of economic growth in contemporary knowledge-based economies (OECD, 1996; Quah, 1998) has put the politics of innovation processes on the front burner. But just what exactly one thinks should be done depends crucially on the theory of innovation that is adopted. In this article, we explore how a view of innovation inspired by complexity theory can help us to understand whether we need coordinated interventions to support innovation? And if so, to understand how these can be designed.

Because complexity theory is a developing area of research characterized by a wide – and increasing - range of interdisciplinary applications, the meaning and implications of this approach even within the relatively narrow field of innovation studies are still being negotiated, and different, sometimes conflicting, positions coexist. Therefore, in the next section, we describe what we mean by a complexity perspective to innovation, contrasting our approach and its policy implications with the traditional "linear" model of innovation and with broader "systemic" approaches developed more recently. Having broadly outlined the theoretical framework on which the analysis is based, in section 3 we explore its implications for coordinated interventions in support of innovation, with reference to two case studies. Finally, in section 4, we derive some concluding remarks for policy design.

2. A complexity perspective to innovation

Innovation theory and innovation policy

Economic and organizational theories have progressively moved beyond the traditional linear view[1] of innovation - which conceptualizes innovation as a sequence of well defined, temporally and conceptually distinct, stages - in favour of systemic approaches that interpret innovation as a complex process, involving many actors, their relationships and the social and economic context in which they are embedded. The influential literature on national systems of innovation, which

[1] Although rarely codified in the economic literature, the linear model has for a long time been widely shared, often implicitly, in the academic discourse. For a comprehensive reconstruction of its historical development, see Godin, 2006.

emerged at the beginning of the 1990s with the path-breaking contributions by Lundvall (1988; 1992), Freeman (1988) and Nelson (1988; 1993), has highlighted the interplay of a wide range of factors, organizations and policies influencing the capabilities of a nation's firms to innovate (Nelson, 1993). At the same time, this focus on the cognitive aspects of innovation has fostered interest in interactions among agents as sources of new knowledge: direct interactions among people are considered the main modes of transmission and creation of tacit knowledge thought to be a key source of innovation processes[2]. Researchers have begun to study various forms of cooperation between firms directed at developing innovations (Freeman, 1991; Mowery and Teece, 1996), including user-producer interactions (Von Hippel, 1978; Lundvall, 1985; Russo, 2000). The role of proximity - cognitive, technological, social or geographic - in fostering innovation processes has also been explored theoretically and empirically (Audretsch and Feldman, 1996; Jaffe, 1986; Nooteboom, 1999; Lundvall, 1992; Balconi, Breschi and Lissoni, 2004).

Paralleling the evolution of the academic discourse on innovation, the policymakers' theoretical understanding of innovation processes has also evolved, particularly in Europe (Mytelka and Smith, 2002). In line with a systemic approach to innovation, it has been acknowledged that innovation policies must be implemented through interventions that involve not only the activities of basic scientific research, development and commercialization of research outcomes, but also the productive activities of firms and the social and institutional contexts in which they operate (EC, 2003). Interest in social interactions as a locus for innovation has led policymakers to assign particular importance to supporting the activities of clusters, intended as aggregations of organizations, as well as networks of cooperation among heterogeneous actors (Audretsch, 2002; EC, 2003; European Council, 2000).

However, despite the widespread attention dedicated to these issues, and despite the quantity of funds that are being channelled into innovation-supporting

[2] This issue was first raised in the literature by Hagerstrand (1965, 1970) and Polanyi (1969).

activities[3], designing interventions that are consistent with a systemic approach to innovation often proves to be challenging (Russo and Rossi, 2009).

On the one hand, broad theories of innovation do not lend themselves to a quick translation into simple "policy recipes". In fact, conceptualizing innovation as a complex process means that it is not possible to devise context-independent ways to support it. Two of us have argued elsewhere (Russo and Rossi, 2008) that innovation theories should not be used to derive general policy guidelines but should more modestly support policymakers in formulating and addressing questions that are appropriate to their particular socioeconomic and institutional contexts. In this sense, successful innovation policies should have a local dimension, that is, they should be "rooted in localities identified by sets of relations within specific communities of people, firms and institutions" (Bellandi and Di Tommaso, 2006).

On the other hand, the features of complex innovation processes are often not very well understood theoretically, especially when they involve a multitude of different economic agents. There is therefore a need for improved theoretical and empirical understanding of these processes, of the economic actors that drive them and of the channels through which communication processes take place and lead to the development and consolidation of innovations.

An important consequence of the gap between the evolving theoretical interpretation of innovation processes and the actual implementation of innovation policies is that many interventions that are claimed to be in line with a "systemic" approach to innovation in fact owe much to the linear model, as the European Commission (2003) has explicitly admitted.

To help fill the gap between theoretical understanding and policy implementation, this article discusses the problem of whether and how to implement coordinated interventions that build upon a view of innovation inspired by complexity theory,

---

[3] According to our estimates, expenditure on innovation-related interventions in the EU (broadly intended to include Framework Programme interventions as well as innovation-supporting measures sponsored by the Structural Funds) increased from approximately 6,052 million euro per year in the period 1994-1997 to approximately 7,404 million euro per year in the period 2002-2005 (figures computed from data presented in Rossi, 2007).

and particularly upon a specific approach called “dynamic interactionism” (Lane and Maxfield, 1997, 2005; Lane, 2006).

Rethinking innovation: a dynamic interactionist perspective

Complexity approaches to innovation formalize numerous insights that were first developed in the context of qualitative studies of innovation and technological change. Broadly speaking, complexity has come to mean a particular phenomenology that can be called “interactionism”: it deals with systems characterized by a set of heterogeneous entities that interact with one another, organized in a network structure, that is, with some rules about who interacts with whom. As a result of agents’ interactions, the agents’ own properties change; interactions are local, while the objects of interest are usually global: they depend on patterns of interaction events that are stable over a time scale much longer than the interactions themselves. Such patterns self-organize, that is, they arise through interactions among the entities. When the resulting patterns can be described in a language that makes no reference to the underlying entities and their interactions, they are called “emergent”. The study of self-organization and emergence constitutes the primary goal of complexity research.

According to Lane and Maxfield’s dynamic interactionist theory of innovation (1997; 2005), interactions among heterogeneous agents, over time, can consolidate into structures able to support innovation processes. Both individuals and organizations, belonging to “tangled hierarchies” (Lane, 2006; Lane, Read and van der Leeuw 2009), can generate changes in the organization of the relationships among agents and artifacts in the economic system and, in turn, their structure and the functionalities that they support can be modified by the actions of entities positioned at other levels in the social hierarchy.

The theory pays great attention to the role of “ontological uncertainty”, meaning that economic agents find it impossible to evaluate future outcomes because they do not even know who or what will affect the results of their own actions (Lane and Maxfield, 2005). In order to explain how innovation processes take place in conditions of ontological uncertainty, a three-level theoretical framework is presented (Lane, Malerba, Maxfield and Orsenigo, 1996; Lane and Maxfield, 1997, 2005, 2008; Russo, 2000, 2005). First, at the level of the individual agents, ontological uncertainty can be managed by agents in the short term through the adoption of a “narrative theory of action” (Lane and Maxfield, 2005).

Second, at the level of agents’ interactions, innovation processes are claimed to result from particular kinds of relationships called “generative relationships” (Lane and Maxfield, 1997, 2005). A relationship’s potential to generate innovations can be monitored by paying attention to some of its features: the agents involved in a potentially generative relationship must in their interaction share a focus on the same artifact or agent (aligned directedness); agents must differ in terms of expertise, attributions or access to particular agents or artifacts (heterogeneity); they must seek to develop a recurrent pattern of interactions from which a relationship can emerge (mutual directedness); they must be able to carry out discursive interactions, outside the conventional exchanges that are generally confined to requests, orders, declarations (right permissions); interactions can prove more productive if agents have the chance to work together on a common activity (opportunities for joint action).

Third, at the level of market systems, agents are guided by (formal or informal) “scaffolding structures” that allow them to better manage ontological uncertainty and to create “competence networks” able to sustain and reproduce the functionalities needed for the system to survive over time. While generative relationships lead to the introduction of innovations, innovations in turn feed structural change into agent-artifact space. The process takes place through a bootstrap dynamics where new generative relationships induce cognitive shifts that lead to actions that in turn create possibilities for new generative relationships. The structural characteristics of the system in terms of the distributions of agents in multidimensional spaces, of their networks of communication, relationships and interactions are key elements that sustain the innovation process (Antonelli, 2008).

This ontology has been used to analyze two examples of coordinated interventions in support of innovation, presented in the next section. In both cases, we could rely on microdata on inter-organizational interactions taking place in the context of such coordinated interventions, which we have studied through network analysis. Although not by itself explanatory, network analysis can help highlight certain features of inter-organizational interactions whose meaning and purpose can then be interpreted through the prism of our theory of innovation. The analysis has then been complemented by qualitative interviews.

3. Empirical analysis

The case studies discussed in this paper concern two very different kinds of coordinated interventions in support of innovation, both of which have been implemented in Italian regions whose economic structure is characterized by the presence of clusters of firms organized in industrial districts. These interventions are presented not as examples that can be immediately generalized to other regional contexts, but rather to illustrate what it means to devise interventions that take into account the complex nature of innovation processes.

A public policy intervention supporting heterogeneous innovation networks

The "Innovazione Tecnologica in Toscana" programme, funded within the ERDF Innovative Actions framework (henceforth, RPIA-ITT), was implemented by Tuscany's regional administration in the period 2001-2004; the programme was conceived as a pilot test for the use of further structural funds in the region.

RPIA-ITT intended to promote development in the regional economy through the creation of networks of organizations tasked with carrying out innovative projects. Project proposals were solicited within four action lines. Two of them intended to promote technology transfer and diffusion of innovation in, respectively, the geographical area of Western Tuscany (action line 1) and a set of technological applications in the fashion industry (action line 2), both of which had recent histories of sluggish growth. The other two were targeted to high-tech applications, optoelectronic technologies (action line 3) and biotechnologies (action line 4). The programme required heterogeneous networks (the call for tender requested each cooperation network to comprise at least four firms, one university or public research centre, and one public, private or mixed company having among its statutory aims the provision of services to firms) and encouraged participation by SMEs, which in fact constituted a large share of the actors taking part in the programme (if we consider only funded projects, half the participants were SMEs, and almost one third were small manufacturing companies with less than 30 employees). Table 1 summarizes the main data on the programme.

Table 1. A synthetic overview of the RPIA-ITT programme

	applications	funded projects
number of projects	36	14
number of partners	528	264
number of different organizations involved	409	203
number of SMEs featuring as partners	295	129
number of different SMEs involved	262	118
organizations involved in more than one project	58	22
budget (in euro)	15.504.764*	6.494.298**
* of these, 11.661.951 euro were to be financed by the Region		
** of these, 4.703.029 euro were financed by the Region		
Action lines		**% available resources**
1. Promoting technology transfer and diffusion of innovation in Western Tuscany		29%
2. Promoting technology transfer and diffusion of innovation in the fashion industry: textiles, clothing, shoes		27%
3. Promoting technological development and industrial applications of optoelectronic technologies		21%
4. Promoting technological development and industrial, agricultural, environmental appliications of biotechnologies		23%

For purposes of the present article, it is particularly interesting to explore the extent to which this intervention has fostered the creation of innovation networks which have been able not only to set up good quality project proposals but also to exploit them in order to give rise to further “cascades of innovation”. One particularly interesting feature of the set of organizations that applied to the programme is that many (58 out of 409, that is 14.2%) were involved in more than one application, and that a small share of these (10 organizations, or 2.5%) were to perform activities corresponding to one quarter of the financial resources of the entire programme. It is apparent, therefore, that a few organizations played key roles in the policy programme. We set out to investigate these roles by studying, on one level, the relationships between organizations within each project, and, on another level, the relationships between organizations involved in different projects. To do so, we first reconstructed the networks of relationships internal to each of the 13 funded projects for which such information was available. We did so on the basis of the person-months committed by each organization to each work module of the project, at three different times (presentation of the request, beginning of the work, and report on the results achieved). Then, at the level of the entire set of 36 (funded and non-funded) projects, we constructed the two-mode network describing the participation to one or more project proposal on the part of the 409 organizations involved in the programme. From this large network we extracted the one-mode network of relationships between the 36 projects (participation of the same organization to more than one project indicated a connection between these projects) as well as the one-mode network of relationships between the 409 organizations (participation of the same two organizations to the same proposal indicated a connection between these organizations).

Here we present a brief summary of our findings[4]. Apart from two isolated projects whose participants were not present in other networks (and which failed to secure funding), most projects were connected through one or more organizations in common. We focused in particular on the 58 organizations that were present in more than one project: since some of them were present in numerous projects, they actually featured 177 times as project partners, out of a total of 528 participations (33.5%).

With respect to the features of these actors, we first notice that many of them had already collaborated, before and outside the RPIA-ITT programme, to other projects funded by the European Commission, by the regional administration, and by national government agencies. Furthermore, many had also been involved in a set of talks set up by the regional administration before the launch of the RPIA-ITT programme. This suggests that the RPIA-ITT's networks were activated by a relatively small set of organizations that were already accustomed to working with each other and with the regional administration.

[4] A more detailed analysis of these networks and their implications used to derive suggestions for the improved management and evaluation of the policy programme is presented in Russo and Rossi (2009). Our attempt to implement these suggestions in a sample programme is presented in Russo and Rossi (2007).

The network analysis performed on the network of 36 projects that applied to RPIA-ITT showed that there are several separate “k-cores”[5] in the networks. Two of these k-cores were composed mainly of projects submitted to action lines 1 and 2; the funded projects in this group were assigned 45% of the RPIA-ITT’s total budget.

The organizations connecting these projects, both located in Pisa, are the most central[6] in the network described above: Scuola Superiore S.Anna (an influential postgraduate research institution in Italy) and CPR (a research and technology transfer consortium that comprises several local administrations and the main provincial academic institutions, including S.Anna).

The third k-core was composed of 7 projects that have been promoted by a network of research centres specialized in optoelectronics technologies, a field characterized by technological convergence in a vast range of applications. The interviews confirmed the presence, in the region, of an established network of internationally renowned public research institutions in the optoelectronics field (CEO, INOA, CNR-IFAC) and of a company, El.En, worldwide leader in the production of laser technology. This is complemented by a tight fabric of SMEs involved in the production of high-technology instruments for optic technology and of related software applications. In order to set up a large number of RPIA-ITT projects, these organizations were able to rely on their previous experience of successfully bidding for regional and other public funds, since optoelectronics had already been a focus of regional policy during the 1990s.

Therefore, the network analysis highlights the important role played by some research centres and large firms (already used to collaborating with each other and with the regional administration, and to monitoring funding opportunities) in the coordination of a number of project proposals.

---

[5] K-cores in a network are groups of connected vertices which have at least k links with each other. See Moody and White (2003) for details.

[6] Centrality indexes measure the relational properties of the nodes in a network (Degenne and Forsé, 1999; Wasserman and Faust, 1994). Degree centrality measures the number of links of a node with all the others. The betweenness centrality index of a node is the proportion of paths between all pairs of nodes in the network that contain that node (it measures to what extent each node provides a connection between other pairs of nodes). In the measurement of closeness centrality the central nodes of the network have minimum geodeticdistance from all the other nodes. In our analysis, the use of these different measures of centrality provided similar results.

The analysis of the individual projects' networks and the qualitative interviews show that the requirement of heterogeneous competences within each project enabled many organizations to interact with partners with whom they might not have worked otherwise. However, the recruitment of certain organizations, specifically small companies and university departments, proved difficult since both, for different reasons, were unaccustomed to collaborative innovation and were often ill-equipped to deal with the complicated administration of EU-funded programmes. In these cases, their involvement had to be mediated by a set of service providers. Despite having different structural characteristics, different behaviours and different objectives, all these providers appeared to engage in a set of activities, such as training, certification, research and technology transfer, that allowed them to weave a close fabric of relationships with both manufacturing firms and other local actors (trade associations, local administrations, universities). These organizations can be defined as "multivocal": they understand several "languages" − from academic research to the specific production technology − and they may interpret the needs of actors that might not even be able to express them. As such, they were essential in order to recruit actors with specific competences, and in many instances, they were also able to develop good quality project proposals and to effectively disseminate the projects' results.

A private technology broker sponsored by a group of large firms

Our second case study involves an organization – called Centro di Ricerca and Innovazione Tecnologica (CRIT) – that acts as a "technology broker" primarily but not exclusively for many leader firms in Modenese and Emilian mechanical engineering industry. A cross between an association and a firm, CRIT was an indirect consequence of a 1999 law that offered funding and incentives for universities to connect with other research centers in the region of Emilia Romagna, and that took advantage of some national level-financing for "technology districts" (Sardo, 2009). One proposal involved linking a network of university research centers to a "Science technology park" that would be placed in Spilamberto, a town in an area densely packed with mechanical firms on the border between the provinces of Modena and Bologna. The project had the support of local governments, who saw a chance to rehabilitate a large swath of industrial land long in disuse, of the university, and of some of the larger mechanical firms in the region, fourteen of which established CRIT in 2000. They each committed to paying what was for such leader firms a relatively limited amount – 25,000 euros annually – to sustain the organization. The idea was that CRIT would have a small technical and administrative staff that could draw upon the expertise of its member-owners to analyze the demand for innovation in the region. Using that knowledge, it would then aim to broker the demands for technology of the mechanical industry, particularly of member firms, and sources of supply. These would tend to be located in the proposed technology park, which would aim to organize that supply relying especially on regional research centers and universities.

However, efforts to establish the technology park have foundered amid political infighting in the region, and its future remains even today uncertain. CRIT, meanwhile, has not only survived, it has added eleven new members to its original fourteen founders (see Table 2). Most importantly, it has done so because it has substantially re-oriented its *raison d'etre* by remaking itself as an organization that aims more generally to stimulate "collaborative innovation," working primarily but not exclusively with member firms that are generally not direct competitors, but that often share at least some overlapping technologies and perhaps suppliers.

Table 2. CRIT's members by year, 2000-2008

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ali									
Beghelli									
Caprari									
CNH Italia									
CEFLA									
Cineca									
CMS									
Datalogic									
Ducati Energia									
Ferrari									
G.D									
Gruppo Fabbri									
Hydrocontrol									
IMA									
Italtractor ITM									
Rossi Motoriduttori									
Sacmi									
Saima Avandero									
SCM Group									
Selcom Elettronica									
Sitma									
System									
Technogym									
Tetra Pak									
WAM Group									
Number of members	14	14	16	16	16	17	17	19	25

The most innovative feature of CRIT is the combination of activities in which it engages. In particular, CRIT combines services to firms of two basic sorts that we conceptualize as either “switches” or “spaces”. CRIT acts as a switch when it activates one-to-one relationships (generally between a member firm and a non-member firm or research organization). Switching is classic brokerage, in which CRIT is approached with a demand for a service or for information, uses data in internal databases or conducts an external search, and either provides the service using internal engineers or connects the client to an organization that can provide the desired service. Switching includes R&D projects, technology “scouting,” proposals for external funding (e.g. from the EU), or analyses of competitors’ patenting patterns conducted by a small consultancy that is a wholly owned subsidiary of CRIT. It serves instead as a space of potential interactions when it creates opportunities for open dialogue. CRIT does this by hosting events such as “thematic working tables”, seminars, technology tours, group training events, and meetings of technical directors. These events are sometimes proposed by CRIT, but are often born of initiatives proposed by member firms. The key is that they take place in a setting in which participants can openly share ideas, but are structured enough that the conversation will be limited to particular topics of “technological” relevance. There is one particularly important type of event – offered free to members, and off limits to non-members – that is intended both to ensure that members are familiar to each other and to give CRIT personnel collective guidance on the direction of other services desired: this is the meeting of technical directors (RDT), held approximately four times per year.

In the period 2000-2008, there were 187 “space” events, against 295 “switches. 109 organizations participated in just spaces events, 34 in just switches, while 60 took part in both sorts. Most participants to space events are manufacturing firms, primarily engaged in mechanical, electronic, or automotive industries. Services that we classify as “switch” are more likely to also involve non-manufacturing organizations (including especially research centers and universities) with complementary competencies especially for R&D and other technological “scouting.” In general, the population of organizations involved changes over time: some organizations remain very central, others are involved in just one event. For many, the fact that they have very particular competencies explains their occasional involvement in a seminar, or in a particular technical meeting.

In order to understand the nature and dynamics of the interactions space enabled by CRIT – without which such interactions would have not occurred - we analyzed the pattern of co-participation of different organizations to the events organized by CRIT. We created a large two-mode network involving all CRIT events and all participants in the period 2000-2008. Then, from this we extracted several sub-networks on the basis of temporal intervals (different years) and/or of types of events (switch or space, or particular types of switch or space events). Some of these subnetworks have also been transformed in one-mode networks showing relationships between events, or relationships between participants. Here we present a brief summary of our findings[7].

First, we observe that the network generated by serviced offered by CRIT grew around a nucleus of more active and "central" actors. Mechanical firms have the highest centrality[8] in space events; among these, member firms are even more central. The most central group is a nucleus of seven that are especially active: GD, IMA, Tetrakpak, Gruppo Fabbri, Selcom, System, and CMS. These are slightly more central than another also quite central group that includes Sacmi, italtractor, Rossi Motoriduttori, CNH, and Datalogic. These are also, notably, the same firms who generally have a high centrality in switch events. But for switch events, we see high centrality also for nonmembers, including especially research centers and universities.

Second, the analysis of "islands"[9] within each one-mode network of participants over time shows that, even among central actors, there is a nucleus that is even more central and that tends to interact a great deal (and that has become even

[7] A more detailed analysis of the CRIT case study and of these networks is presented in Russo and Whitford (2009).
[8] Most of our analyses were performed using betweenness centrality indexes, but consistent results were found when degree centrality was used instead.
[9] "Line islands" within a network allow the identification of important subnetworks: groups of connected vertices that are more densely connected with each other than with other neighbouring vertices in the network. The algorithm is implemented in Pajek (see de Nooy, Mrvar and Batagelj, 2005).

more stable since 2005, the year that CRIT became fully independent of the Ex-Sipe consortium). It is a nucleus of members that is extremely active, and their activities are highly varied (by type of event, and therefore by the potentiality of interactions with other participants occasionally present). Only a few members do not participate regularly, not even to the meetings of technical directors: our hypothesis is that they nonetheless remain members because the cost to remain involved in this prestigious club is relatively low.

Third, there have been changes in the services asked over time. Initially, many firms asked for R&D projects and for technological "scouting". Over time, the importance of "space" events has increased considerably – almost as if member firms "learned" how to best use CRIT over time. CRIT too learned from experience, by introducing new services some of which, if not important quantitatively, do show that CRIT experiments in response to needs signalled by firms (thematic "technical tables" on various subjects, tours, PatMole, Lapcos). In this way, CRIT can itself become part of other organizations' networks and can itself learn.

4. Conclusion: supporting collaborative innovation in a complexity perspective

Both these cases represent examples of coordinated interventions that have been successful in promoting innovation in their specific contexts. As such, their interpretation in light of some concepts of complexity theory can help us derive some helpful indications for policy design.

First of all, both interventions were inspired by fairly conventional views of innovation, but in practice they ended up unfolding along unconventional lines.

In the case of RPIA-ITT, the setup of heterogeneous innovation networks was still underpinned by a fairly rigid view of what would be an appropriate "division of innovation labour" within the networks: according to the regional administrators who set up the programme, the projects should have consisted in exercises of technology transfer from universities and research centres – which would have developed relevant innovations – to firms that would implement them, sometimes fostering the development of particular applications; small firms would be assigned in most cases the mere role of testers of innovations developed elsewhere.

Because of the short duration of the RPIA-ITT programme, the projects were in fact co-ordinated by a set of research centres and some large firms already experienced in inter-organizational collaborations and in the use of public sponsorships for their research activities. Nonetheless, the small firms involved in the programme became something more than mere users of the projects' results, since thanks to their involvement in these activities they became more likely to be involved in further innovation projects: for them, the RPIA-ITT was a learning experience, facilitated by the mediation of service providers. The projects (and even the planning of those that were not funded), provided a temporary space which allowed unusual interactions and novel learning experiences. The requirement of heterogeneity, which in the eyes of the designers of the programme should have simply better allowed knowledge transmission from universities and research centres to firms, provided almost by accident opportunities for innovation.

In the case of CRIT, the main function of the technology broker in the eyes of its founders should have been that of favouring the match between their "demand" for technology and business information and the "supply" of that knowledge available elsewhere. Moreover, the localization within the technology park would have further emphasized the importance of one-way technology transfer from the world of university and basic research to the applied research performed by industry. However, the organization and its founders learned over time that the classic brokering function was not the most interesting way to use the organization. Rather, CRIT could allow members opportunities for discussion and the right "permissions" to talk to other organizations, creating a kind of "public space" which according to Lester and Piore (2004) favours innovation since it provides "a venue in which new ideas and insights can emerge, without the risk that private appropriation will undermine or truncate the discussion".

Therefore, both interventions were conceived as mere technology transfer exercises, but much of their value added came from the fact that they allowed the creation of spaces for open-ended discussion, where the "interpretative ambiguity" (Fonseca, 2002; Lane and Maxfield, 1997) necessary for innovation could emerge.

This leads us to the second point, which relates to the importance of structuring interactions. In both cases, the space for interactions was structured, designed (sometimes involuntarily) to provide the conditions that enhance generative potential. In the RPIA-ITT, the involvement of service providers allowed the recruitment of small firms and university departments that were relatively unaccustomed to dealing with each other, and helped achieve some degree of heterogeneity in the networks. In CRIT, heterogeneity is monitored by the members, which are careful to involve organizations that are not direct competitors. In both cases, also opportunities for joint action and the right permissions for agents to interact with each other were present.

Within heterogeneous networks, an important role is played by mediating organizations capable to engage in multivocality, as opposed to traditional brokering activities: that is, the organizations mediating interactions are not simply required to transmit information between agents that do not know each other, bridging a "structural hole" in the network (Burt, 1992), but they need to facilitate the direct interactions among these agents, and to do so they need to be able to communicate with each. Service providers in Tuscany, and CRIT's staff, are the agents able to provide such multivocality in each case.

Third, in the theory of innovation that we adopt, a very important role is played by the scaffolding structures that support complex innovation process over time. Both the RPIA-ITT programme and CRIT can be seen as scaffolding structures providing some continuity in support of innovation processes, which often unfold over long temporal scales. In the case of RPIA-ITT the short duration of the programme was perceived as a serious limiting factor, but not a critical impediment to innovation, since the main actors involved in the programme were able to exploit a wide range of policy instruments to support their innovation processes; these main actors had already been involved in other policies, and continued to do so after RPIA-ITT, effectively using the regional policy infrastructure as a scaffold for their innovation activities.

It took CRIT and its members several years in order to learn how to use the organization productively, and this was made possible by the continuity in commitment of its members. Interventions supporting collaborative innovation are useful when they last over a long period of time -- the development of new technologies and the understanding of how to exploit them commercially are lengthy processes, after all. Especially in the case of radically new technologies that open up new market systems (Lane and Maxfield, 2009), scaffolding structures are important in order to foster the creation of the competences necessary to ensure that the technologies can be maintained and diffused.

Finally, the comparison between these two cases highlights that there is no "one size fits all" approach to sustaining innovation through collaborative processes. The two interventions considered were inspired by a fairly conventional view of innovation, but they worked because their implementation was tailored to the actual features of the local innovation systems. For example, the presence of numerous service providers, often very sector-specific, is a feature of the Tuscan regional innovation system which is not present everywhere. The explicit involvement of these actors in the programme was very important for the process of network construction. In the case of CRIT, the emergence of this kind of organization may not have been possible had there not been a critical mass of large local firms which are active in the same sector but are not in direct competition with each other. It is possible to generalize this conclusion by claiming that any successful coordinated intervention in support of innovation requires an effort to identify, ex ante, the key actors that are best able to construct networks of relationships that can support innovation processes, and to create the conditions to enhance the generative potential of these relationships.

One final remark concerns a possible research agenda with respect to these issues. We believe that improving the tools that enable us to study in detail certain examples of networks of relationships can help us improve our ability to monitor and support innovation processes. The analysis of dynamic temporal networks and of multi-level networks involving agents at different levels of social organization (both organizations and individuals) should help in this sense, as should the development of agent-based models in order to construct scenarios relevant to innovation policies. A better integration of these quantitative techniques with ethnographic research should also help to build a set of tools to design and analyze policies.

The performance of pilot case studies involving the design, management, monitoring and evaluation of coordinated interventions supporting innovation should also help policymakers to learn how to use these tools.

Bibliographical references

Antonelli, C. (2008) *Localized technological change: towards the economics of complexity*, London: Routledge.

Audretsch, D. B., Feldman, M. P. (1996) Spillovers and the geography of innovation and production, *American Economic Review*, 86 (3): 630-642.

Audretsch, D. (2002) *Entrepreneurship: A survey of the literature*. Bruxelles: European Commission, Enterprise Directorate General.

Balconi, M., Breschi, S., Lissoni, F. (2004) Networks of inventors and the role of academia: an exploration of Italian patent data. *Research Policy*, 33 (1): 127-145.

Bellandi, M., Di Tommaso, M. (2006) The local dimensions of industrial policy. In Bianchi, P., Labory, S. (Eds.), *International handbook on industrial policy*, Cheltenham, UK: Edward Elgar, 342–361.

Burt, R.S. (1992) *Structural Holes: The Social Structure of Competition*. Harvard University Press.

European Commission (2003) *Investing in research: an action plan for Europe*, COM(2003)226, Bruxelles: Commission of the European Communities.

European Council (2000) *Council Decision on a Multiannual Programme for Enterprise and Entrepreneurship, and in Particular for Small and Medium Enterprises*

de Nooy, W., Mrvar, A., Batagelj, V. (2005) *Exploratory Social Network Analysis with Pajek*. Cambridge: Cambridge University Press.

Degenne, A., Forsé, M. (1999) *Introducing social networks*. London, UK: Sage.

Fonseca, J. (2002) *Complexity and innovation in organizations*, London: Routledge.

Freeman, C. (1988) Japan: A new national system of innovation? In Dosi, G., et al. (eds.), *Technical change and economic theory*, London, UK: Pinter Publishers, 38-66.

Freeman, C. (1991) Networks of innovators: A synthesis of research issues. *Research Policy*, 20: 499–515.

Godin, B. (2006) The linear model of innovation: the historical construction of an analytical framework, *Science Technology Human Values*, 31(6): 639-667.

Hagerstrand, T. (1965) Quantitative techniques for analysis of the speed of information technology. In C. A. Anderson, M. J. Bowman (Eds.), *Education and economic development,* Chicago, IL: Aldine Publishing Company, 244–280.

Hagerstrand, T. (1970) What about people in regional science? *Papers of the Regional Science Association*, 24, 7–21.

Jaffe, A.B. (1986) Technological opportunity and spillover of R&D: evidence from firms' patents, profits and market value, *American Economic Review*, 76(5):985-1001.

Lane, D. A. (2006) Hierarchy, complexity, society. In D. Pumain (Ed.), *Hierarchies in natural and social systems*, Dordrecht, The Netherlands: Kluwer, 81-120.

Lane, D.A., Maxfield, R. (1997) Foresight, complexity and strategy, in Arthur, B., Durlauf S. and D.A. Lane (eds.), *The economy as a complex evolving system II*, Reading, MA: Addison-Wesley.

Lane, D.A., Maxfield, R. (2005) Ontological uncertainty and innovation, *Journal of Evolutionary Economics*, 15(1): 3-50.

Lane, D.A., Maxfield, R. (2009) Building a New Market System: Effective Action, Redirection and Generative Relationships, in D.A. Lane, G. West, S. van der Leeuw and D. Pumain, eds., Complexity perspectives on Innovation and Social Change. Dordrecht: Springer Methodos Series, 263-288.

Lane, D. A., Malerba, F., Maxfield, R., Orsenigo, L. (1996) Choice and action. *Journal of Evolutionary Economics*, 6, 43–76.

Lester, R., Piore, M. (2004) *Innovation: the missing dimension*. Cambridge MA: Harvard University Press.

Lundvall, B.A. (1985) *Product innovation and user-producer interaction*, Aalborg: Aalborg University Press.

Lundvall, B.A. (1988) Innovation as an interactive process: from user-producer interaction to the national system of innovation, In: Dosi, G., et al. (eds.), *Technical change and economic theory*. London: Pinter Publishers, 349–369.

Lundvall, B.A. (1992) *National Systems of Innovation. Towards a theory of innovation and interactive learning*. London: Pinter Publishers.

Mowery D., Teece, D. (1996) Strategic alliances and industrial research. In R. Rosenbloom, W. Spencer (Eds.), *Engines of innovation: U.S. industrial research at the end of an era*. Boston, MA: Harvard Business School Press, 111-129.

Mytelka, L, Smith, K. (2002) *Policy learning and innovation theory: an interactive and co-evolving process*, Research Policy, 31 (8/9): 1467-79

Nelson, R. R. (1988) Institutions supporting technical change in the United States, in Dosi et al. (eds) *Technical change and economic theory*, London: Pinter, 312-329.

Nelson, R. R. (1993) *National innovation systems: a comparative analysis*, New York: Oxford University Press.

Nooteboom, B. (1999) Innovation, learning and industrial organization, *Cambridge Journal of Economics*, 23, 127–150.

Organization for Economic Cooperation and Development (1996) *The knowledge-based economy*, Paris: OECD.

Polanyi, M. (1969) In M. Grene (Ed), *Knowing and being*. London, UK: Routledge and Kegan Paul.

Quah, D. (1998) A weightless economy, *UNESCO Courier*, December,18-21.

Rossi, F. (2007) Innovation policy in the European Union: Instruments and objectives. *MPRA Paper*, Munich, Germany: University Library of Munich.

Russo, M. (2000) Complementary innovations and generative relationships: An ethnographic study. *Economics of Innovation and New Technology*, 9, 517–557.

Russo, M. (2005) Innovation processes and competition: China challenges Sassuolo. How do innovation processes in industrial districts are affected by competition from new market systems. In *Proceedings of the conference in honor of Professor Sebastiano Brusco, Clusters, Industrial Districts and Firms: The Challenge of Globalization*, September 12–13. http://www.economia.unimore.it/convegni seminari/CG sept03/ naviga.html.

Russo M., Rossi, F. (2007) Politiche per l'innovazione: dalla valutazione alla progettazione, *Materiali discussione DEP*, 565, Unimore.

Russo M., Rossi, F. (2009) Cooperation partnerships and innovation. A complex system perspective to the design, management and evaluation of a EU regional innovation policy programme. *Evaluation*, 15(1): 75-100.

Russo M., Whitford, J. (2009), Industrial districts in a globalizing world: A model to change, or a model of change, *Materiali discussione DEP*, 615, Unimore.

Sardo, S. (2009), Brokeraggio tecnologico nel settore metalmeccanico in Emilia-Romagna: dal Parco Scientifico Tecnologico ex-SIPE a CRIT srl, *Materiali discussione DEP*, 614, Unimore.

Von Hippel, E. (1978) Users as innovators. *Technology Review*, 80(3): 1131–1139.

Wasserman, S., Faust, K. (1994) *Social network analysis: Methods and applications*. Cambridge, UK: Cambridge University Press.

RECENTLY PUBLISHED "Materiali di Discussione"

N. 618 ***Returning and Sharing Memories*** *Genesi e sviluppo di un progetto per l'uso del "passato comune" italo-etiope (1935-1941),* by Paolo Bertella Farnetti [September 2009]

N. 617 *The skew pattern of implied volatility in the DAX index options market,* by Silvia Muzzioli [July 2009].

N. 616 - *Political institutions and central bank independence revisited,* by Davide Ferrari, Barbara Pistoresi and Francesco Salsano [July 2009].

N. 615 - *Industrial districts in a globalizing world: A model to change, or a model of change,* by Margherita Russo and Josh Whitford [July 2009].

N. 614 - *Brokeraggio tecnologico nel settore metalmeccanico in Emilia-Romagna: dal Parco Scientifico Tecnologico ex-SIPE a CRIT srl,* by Stefania Sardo [May 2009].

N. 613 - *The Officina Emilia Initiative: Innovative Local Actions to Support Education and Training Systems,* by Paola Mengoli and Margherita Russo [May 2009].

N. 612 - *Strategia di Lisbona per l'inclusione sociale e politica agricola comune: un esempio della difficile coerenza tra azioni di policy europee,* by Paola Bertolini and Marco Montanari [April 2009].

N. 611 - *The recent reforms of the Italian personal income tax: distributive and efficiency effects,* by Massimo Baldini and Daniele Pacifico [March 2009].

N. 610 - *La City di Torino. Alla ricerca del quartiere finanziario della città a metà Ottocento,* by Simone Fari [March 2009]

N. 609 - *Which European model for elderly care? Equity and cost-effectiveness in home based care in three European countries,* by Francesca Bettio and Giovanni Solinas [February 2009]

N. 608 - *Immigrant Links, Diasporas and FDI. An Empirical Investigation on Five European Countries,* by Sara Flisi and Marina Murat [January 2009].

"Materiali di Discussione" LATER PUBLISHED ELSEWHERE

N. 546 - M. Murat and B. Pistoresi, *Emigrants and immigrants networks in FDI*, Applied Economics letters, April 2008, **http://www.informaworld.com//content~content=a789737803~db=all~order=author** (electronic publication), **WP No. 546 (December 2006).**

N. 545 - M.Brunetti and C. Torricelli, *The Population Ageing in Italy:Facts and Impact on Household Portfolios*, in M. Balling & E. Gnan & F. Lierman (eds.), Money, Finance and Demography: The Consequences of Ageing, Vienna, Suerf, **WP No. 545 (November 2006).**

N. 532 – M: Montanari, Between European Integration and Regional Autonomy: The Case of Italy from an Economic Perspective, Constitutional Political Economy, Vol. 17, 4, pp. 277-301, **WP No. 532 (March 2006).**

N. 529 - M. Montanari, Knocking on the EU's door: the Political Economy of EU-Ukraine Relations, Journal of Contemporary European Research, Vol.3,1, pp.64-78, **WP No. 529 (February 2006).**

N. 518 - M.Brunetti and C. Torricelli, *Economic Activity and Recession Probabilities: information content and predictive power of the term spread in Italy*, Applied Economics, 2008, in press, **WP No. 518 (December 2005).**

N. 517 - M. Murat and S. Paba (2006), *I distretti industriali tra immigrazioni e internazionalizzazione produttiva*, in B. Quintieri (ed.) I distretti italiani dal locale al globale, Rubbettino, **WP No. 517 (December 2005).**

N. 491 - V. Moriggia, S. Muzzioli and C. Torricelli, *On the no arbitrage condition in option implied trees*, European Journal of Operational Research, forthcoming (doi: 10.1016/j.ejor.2007.10.017), **WP No. 491 (May 2005).**

N. 482 - G. Di Lorenzo and G. Marotta, *A less effective monetary transmission in the wake of EMU? Evidence from lending rates passthrough***,** ICFAI Journal of Monetary Economics, Vol. 4, 2, pp. 6-31, **WP No. 482 (February 2005).**

N. 472 - M.Brunetti and C. Torricelli, *The internal and cross market efficiency in index option markets: an investigation of the Italian market*, Applied Financial Economics, Vol. 17, 1, pp. 25-33, **WP No. 472 (November 2004).**

N. 466 - G. Marotta, *La finanza del settore non profit tra ritardi nei pagamenti e Basilea 2*, Banca Impresa Società, Vol. XXIV, 1, pp. 35-51, **WP No. 466 (September 2004).**

N. 453 - Pederzoli and C. Torricelli, *Capital requirements and Business Cycle Regimes: Forward-looking modelling of Default Probabilities* , Journal of Banking and Finance, Vl. 29, 12, 2005, pp. 3121-3140, **WP No. 453 (February 2004).**

N. 448 - V. Moriggia, S. Muzzioli, C. Torricelli, *Call and put implied volatilities and the derivation of option implied trees*, Frontiers In Finance and Economics, vol.4, 1, 2007, pp. 35-64, **WP No. 448 (November 2003).**

N. 436 - M.Brunetti and C. Torricelli, *Put-Call Parity and cross-market efficiency in the Index Options Markets: evidence from the Italian market*, International Review of Financial Analysis, Vl.14, 5, pp. 508-532, **WP No. 436 (July 2003).**

N. 429 - G. Marotta, *When do trade credit discounts matter? Evidence from Italian Firm-Level Data*, Applied Economics, Vol. 37, 4, pp. 403-416, **WP No. 429 (February 2003).**

N. 426 - A. Rinaldi and M. Vasta, *The Structure of Italian Capitalism, 1952-1972: New Evidence Using the Interlocking Directorates Technique,* Financial History Review, vol, 12, 2, pp. 173-198, **WP No. 426 (January 2003).**

N. 417 - A. Rinaldi, *The Emilian Model Revisited: Twenty Years After*, Business History, vol. 47, 2, pp. 244-226, **WP No. 417 (September 2002).**

N. 375 - G. Marotta, *La direttiva comunitaria contro i ritardi nei pagamenti tra imprese. Alcune riflessioni sul caso italiano,* Banca, Impresa, Società, Vol. XX, 3, pp. 451-71, **WP No. 375 (September 2001).**

N. 303 - G. Marotta and M. Mazzoli, *Fattori di mutamento nella domanda di prestiti ed effetti sulla trasmissione della politica monetaria*, in P. ALESSANDRINI (ed.) Il sistema finanziario italiano tra globalizzazione e localismo, Bologna, Il Mulino, pp. 223-260, **WP No. 303 (April 2000)**

N. 131 - G. Marotta, *Does trade credit redistribution thwart monetary policy? Evidence from Italy*, Applied Economics, Vol. 29, December, pp. 1619-29, **WP No. 131 (1996).**

N. 121 - G. Marotta, *Il credito commerciale in Italia: una nota su alcuni aspetti strutturali e sulle implicazioni di politica monetaria*, L'Industria, Vol. XVIII, 1, pp. 193-210, **WP No. 121 (1995)**

N. 105 - G. Marotta, *Credito commerciale e "lending view"*, Giornale degli Economisti e Annali di Economia, Vol. LIV, 1-3, gennaio-marzo, pp. 79-102; anche in G. Vaciago (a cura di) *Moneta e finanza*, Bologna, Il Mulino, **WP No. 105 (1994).**